The report of the Massachusetts Drainage Commission

THE REPORT

OF THE

MASSACHUSETTS DRAINAGE COMMISSION.

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In 1884, in pursuance of a resolve of the Legislature, the Governor of Massachusetts appointed Messrs. Adams, Stebbins, Converse, Hayden and Tuckerman a commission to investigate conditions affecting the purity of certain rivers of the State and to suggest remedial measures. The commission employed Mr. Eliot C. Clarke as its chief engineer, and Messrs. Joseph P. Davis and Rudolph Hering as consulting engineers. It has recently issued an official report of two hundred and forty-three pages, giving the result of its labors.

The assumption is made at the outset that the rivers in question are seriously polluted by sewage and by manufacturing waste, the degree of pollution in the case of different rivers being duly considered. It is also assumed that the best way to get rid of sewage, when it can safely be adopted, is to discharge it into a large body of fresh water. It is assumed that this is not practicable in the case of the rivers in question.

One of the conclusions reached was that, owing to the impossibility of discharging the sewage directly into streams without first purifying it, it is necessary to exclude storm-water from it entirely. The commissioners say: —

"We do not provide for surface drainage. Situated as we were, it was found to involve a scale of cost which seemed to us entirely inadmissible. It may answer very well when sewage flows freely away into large bodies of water, but if it requires pumping, treating or handling in any form, the accession of rainfall swells the discharge at times to utterly unmanageable proportions and in any aspect is very costly and cumbrous. We think that the figures which we have to present will be sufficiently imposing without one dollar of needless expenditure. In our view the treatment of street scour as sewage is a luxury rather than a necessity of municipal life, and it

seems to us that most of our towns and cities find that their necessities will probably absorb all the funds which they are quite ready to spare."

The prevention of the pollution of streams by the waste of manufacturing establishments is properly regarded as only incidental to the chief purpose of this commission, which is to prevent access of foul or of partially purified sewage to streams from which water is taken for domestic use. This element of the problem is divided into three parts: 1. Relating to towns of which the sewage may be delivered through a common sewer to one common area for purification. 2. Relating to towns of which the sewage may be delivered by a common carrier into the present main outfall system of the City of Boston. 3. Relating to towns of which the sewage must be treated independently, each by itself, or in small groups.

The largest example of the first method is the system proposed for the Mystic River valley. This is to take the sewage of the whole or a portion of Stoneham, Woburn, Winchester, Medford, Belmont, Arlington, Cambridge, Somerville, Melrose, Malden, Everett, Chelsea and Revere, by a sewer which at its lower end is five feet in diameter, with an inclination of 1 to 2,500. This sewer is to deliver at a pumping-station near Pines River in Saugus, where there is a tract of more than 1,000 acres, which may be made available for its treatment. The sewage is to be pumped on to this land and filtered through it, the effluent being discharged a little below the level of half-tide, reaching the sea through Pines River.

The cost of this scheme is estimated at $1,520,000, the interest on the cost of construction at three per cent being $45,600 and the annual charge for maintenance being $20,000. This combined yearly charge is apportioned between the different towns in various amounts ranging from $449.85, in the case of Somerville, to $16,522.44, in the case of Chelsea.

The largest example of the second method is that of the lower Charles River valley for the disposal of the sewage of Waltham, Newton, Watertown, Brighton, Charlestown, Somerville, Cambridge, Brookline, and part of Boston proper. The main sewer of this system has at its lower end a diameter of six feet six inches and an inclination of 1 to 2,800. It delivers into the Boston main sewer

at Huntington and Camden streets. Its cost is estimated at $1,561,000, with a yearly charge for maintenance of $12,000 and for interest of $46,830. To this is to be added an annual payment of the City of Boston for outfall and pumping of $29,650. These costs — in all $88,480 — are apportioned at rates varying from $1,265.06 for a part of Boston proper, to $26,288.21 in the case of Cambridge.

A characteristic example of the third method is to be found in the case of Westborough, where it is recommended to construct a main sewer of fifteen-inch pipe with an inclination of 1 to 1,500 crossing a divide in Park Street by an excavation about twenty-one feet deep and running westerly to a gravelly knoll of about fifteen acres extent, the highest point of which is about seventeen feet above the general level of the adjoining meadow. It is proposed to grade this down by the removal of 33,000 cubic yards of gravel, establishing a level area of ten acres about six feet above the elevation of spring freshets. This land is to be divided into four separate beds to which sewage can be delivered alternately. The cost of the scheme is $45,210. The charge for interest at three per cent would be $1,356.30. No estimate for the cost of maintenance is given. It is proposed that the City of Boston shall contribute $15,000 toward the execution of the work.

The total cost of all the improvements proposed is $3,771,381, on which the yearly interest at three per cent would be $113,141.43.

Concerning those districts which cannot be drained to the Boston main outfall it is assumed that the only admissible process for purifi cation is what is known as intermittent filteration.

Chemical treatment is discarded because of its inefficiency and excessive cost. Broad irrigation or "sewage farming" is discarded because of the large area required and because of the objection to the undertaking of farming operations by a municipality. The commission expresses its objection to chemical treatment as follows:

"It is also the general opinion that chemical processes in their best form will have some effect in removing noxious matter in solution, but all agree that a considerable amount must be left in the effluent. This, however, may be safely discharged into a running stream, if its proportion to the supply of pure water does not exceed five per cent. But we have still to deal with the precipitate — about fifty grains, we will

say, to the gallon. It is very offensive, and not valuable. By subjecting the sludge to methods of pressure, however, most of the water has been expressed without offense, and its weight reduced to about one ton to one hundred and sixty-five thousand gallons of sewage. It is possible that some market-value might attach to this residuum in some localities, but we dare not count upon anything better than gratuitous removal. Finally, the cost of the operation in England is estimated to be just about one shilling per head, or say, twenty-five cents for each person yearly. This does not include interest on the capital invested in the works, land, and so on. By itself, therefore, it does not appear to be financially attractive."

[The cost in England would have to be doubled in calculations for this country.]

Of irrigation it is said that when it is especially favored by circumstances it is the best method, but that it is seldom that these circumstances can be controlled to advantage. The process is thus described:

"By this process, the sewage being conducted to land prepared for the purpose, is suffered to flow over it and be taken up in part by the crops raised upon it. In short, it is an attempt to extract the element of value from the sewage by using it as a fertilizer in farming. The noxious and offensive elements are thus either beneficially appropriated by crops, or are detained in the soil by mechanical filtration, or by long and repeated exposure to the air are decomposed, oxidized, and changed into harmless matters, so that the water which runs off is comparatively pure. More than one hundred towns in England employ this system, and it proves eminently satisfactory where conditions favor its adoption. Its great drawback is the vast area of land required for its successful operation on a large scale. It is stated, for example, in our engineer's report, that Boston would require a farm about as large as the entire township of Brookline, if it wished to realize the whole farming value of its sewage. The best English authorities estimate that one acre of land must be set aside for each one hundred persons. When it is remembered that this land must all be tolerably level and fairly dry, some appreciation is reached of the obstacle which this incident presents to the general adoption of this system. There are subsidiary difficulties which will naturally occur to all. It suggests alarming possibilities of farming on a large scale, by municipal corporations. This prospect may well damp the

enthusiasm of many who would eagerly welcome such a solution of the sewage problem, if sufficient private farming enterprise were available upon tracts of land convenient and adapted to the purpose. . . . Dry or wet, night and day, summer and winter, the same quantity must be taken, or if there be any variation, it is likely to be most when the crop needs it least. And it is this obligation which we fancy would dismay our farmers. But in the absence of such a private demand, it is difficult to see how the work can be carried out without the direct intervention of the municipality. . . .

"In fine, we believe this system to be admirable, if only a number of somewhat intractable conditions, some of which we have indicated, can be controlled. Where all things can be made to work together in harmony, it offers a reasonable probability of at least reducing the expense of getting rid of sewage to a minimum. Where an arrangement can be made to operate it in combination with filtration, so that private agriculturists may take the sewage in such quantities, and at such times, as they may find best for their crops, and, when not desired, can turn it upon filter-beds, we think there would be a fair prospect of attaining the largest measure of utilization with the least possible complication and expense."

The method finally selected for recommendation is what is called in England "Intermittent Downward Filteration" The advantages of this system are so well stated in the report that it would be impossible to improve on the instructive text:

"Intermittent filtration, pure and simple, is the converse of irrigation. The latter is the minimum quantity of sewage applied to the maximum area of land, and permits utilization, as well as purification, to the greatest degree. The former is the application of the maximum quantity of sewage upon the minimum area of land. It permits of only partial utilization, but, in our opinion, of more perfect purification.[1] It frankly abandons all dreams of profit; and in so doing it gets rid of the two greatest drawbacks to the system of irrigation. Having no crop to consider, much less land will suffice, as it is found that the ground will filter ten times as much sewage as any crop upon it can profitably absorb. Having no farming ventures at stake, we are relieved of all the machinery of trade and difficulties of management. Purification, not profit, is the paramount idea. Not that it is impossible, in

[1] This opinion is not well founded.

certain cases, to combine some profitable use with this primary intention, but if so, it is a purely secondary consideration. This system is in effect, nothing but turning certain tracts of suitable land, by skilful preparation, into monstrous filters. There is, properly, no attempt to save any matters held in suspension or solution in the sewage. The object is to get clear of them utterly, whether they be good or bad, precious or worthless, and restore the water to its first estate, pure and undefiled, as it bubbled from the spring. And this wonderful transformation is constantly asserted to be brought about by a faithful application of the filtration process. Its advocates maintain that sewage, passed through ten feet of prepared earth, is good enough for any purpose, and they claim it to be nature's process, and intimate that, after all, it is a mere question of a little more or less remoteness, and every drop of water on earth to-day was sewage not long ago. However that may be, it is sufficient for the present purpose to say that, if properly managed, it does afford a practicable, economical and efficient means of cleansing sewage. The objections to it are five-fold. It is charged to be wasteful, in that it feeds no crop. There is a dread, lest so much sewage on so little land should cause offense, especially in midsummer. Doubters are confident that the land must eventually clog. And finally, it is thought that the cost of the preparation of the land will be excessive, or that the carelessness to be bargained for with ordinary management on a large scale, would render its success utterly problematical. The final arbiter of all such questionings is experience, and that infallible test has decided that these fears are, for the most part, groundless. . . .

"We have, then, no hesitation in recommending the adoption of this system, where, for any reason, broad irrigation is impracticable or undesirable and the ocean unattainable, and we think it likely to prove always a valuable auxiliary, in combination with irrigation, where the surroundings admit of its introduction."

The Commission says, at another point: —

"It almost seems as if earth, at a touch, took every baleful element out of sewage. We wish to emphasize this immunity from all essential pollution to air or water in the neighborhood of such lands, because it is probable that such an apprehension may be aroused at the outset, and it is possible that such baseless fears may be instrumental in prejudicing a feature of the scheme which seems to us to offer a singularly fortunate escape from a very perplexing dilemma."

However, when it comes to its recommendations it does not trust the touch of earth to destroy the baleful element. It says, in connection with Waltham, that filtration might be objected to on the score of danger from the returning effluent to the water supplies of Waltham and Watertown. Again, it says: "Any sewage field which might be fixed upon should not even filter in the direction of streams which supply water for drinking." In the case of Marlborough, it is proposed to spend about $22,000 for the sake of reaching remote ground, more than would be required "to reach another equally acceptable were it not for the fact that the effluent from the nearer of the two might affect the Boston water-supply." It recommends that "In Westborough as in Marlborough some additional expense should be faced rather than to run the risk of mixing the results of a possibly imperfect filtration with the drinking-water of any community."

This consideration is never lost sight of by the commission nor by its engineers, and upon it are based most of the recommendations made with reference to all those parts of the district which cannot drain to the Boston outfall.

The general theory on which the recommendations are based may fairly be formulated thus:

1. Unless where access to tide-water can be given in an unobjectionable manner, the sewage must be purified before it enters any stream.

2. Purification by chemical means would not be complete and would cost too much.

3. Broad irrigation when properly controlled secures a perfect effluent and an agricultural advantage, but it would take too much land and would involve the undertaking of farming operations by municipalities. If not always properly regulated it might result in the discharge of crude sewage over the surface into the stream.

4. Intermittent filtration is not subject to these disadvantages; it may be supplemented by irrigation to any desired extent, and its result is perfectly satisfactory.

5. However, to make assurance doubly sure, to avoid an infraction of the statute requiring sewage to be kept out of streams used as

sources of domestic supply, and to see that no unrecognized and unsuspected "virulent poison from a previous sewage pollution" shall enter the water-supply rivers, even intermittent filtration areas must, wherever possible, be moved over beyond the edges of the water-shed and made to drain into some stream not now under the ban of the statute.

6. As the protected water-shed is so large, as the towns are so thick and growing so fast, it is not wise to attempt the purification of their effluent near at hand. So far as possible their sewage should flow into trunk lines and be carried to remote points, as to the Saugus Plain.

7. As the sewage will have to be carried through a costly main sewer, pumped at its point of destination and filtered through earth, everything except sewage must be kept out of it. The luxury of treating other waters would be too expensive.

This formula has been adhered to as closely, as carefully, and as consistently as the nature of things would allow. All of its details have been worked out with indefatigable pains and with great skill and at much cost. If we accept the formula as correct, sufficient, well founded and controlling, no question can be raised from any side as to the satisfactory and conclusive character of the work done.

There is perhaps a point of view from which some details of the scheme, details enormously affecting its completeness and its efficiency, take a somewhat different aspect.

First of all, it is not pleasant to give up our reliance on the good old motto "*Divide et Impera*," which has so long been the watchword of the sanitarian. It has generally been supposed that the more closely the details of cleansing work come under the control and are made to impose their burden upon those producing the waste, the more economical and the more complete might be the result. Under the scheme proposed, it would be at least a matter of indifference to the people of Winchester, for example, whether they sent much or little sewage for transportation through the main sewer, and to be pumped for purification in Saugus; so it would be a matter of indifference to the people of Waltham and Watertown whether they contributed much or little of the flow to be delivered through the Boston

main and pumped at the outfall station. This consideration might seriously affect the magnitude of the problem. Again, there is nothing more rare than a tight sewer, and in many of the towns to be drained the sewers pass through saturated subsoil. That is, they would act as underdrains, and the amount of subsoil water contributed, greater in some places than in others, would, probably, at certain seasons — and these the worst seasons for purification — amount to a very important factor. Then too, it is very well to say that these outlets are provided only for a separate system of sewerage throughout the whole district to be relieved; but who is to regulate this and how exactly will it be regulated? It would be easy, no doubt, to prevent the connection of surface openings in the streets. It would not be easy — at all events for those who control the general system — to police the many towns connected so frequently and so thoroughly as would be necessary to prevent the clandestine discharge of roof and yard water through house-drains, and an enormous volume from this source would come to flood the purification-field at the time when it would — from rain falling directly upon it — be least able to receive sewage.

These considerations suggest a difficulty of great magnitude. It is found in England that where the "separate" system is used, there is a very great increase of flow during rain-storms, and from underground drainage after rains. Bailey Denton says, with reference to Great Malvern: "The sewage proper, measured by the water-supply, amounts to 150,000 gallons a day, but in looking to the dilution due to subsoil water which raises it to 350,000 gallons a day, etc." In Abingdon, the sewage discharged in dry weather amounts to 200,000 gallons "increased to double that quantity in wet weather, the excess being due to the fact that the private sewers communicating with the public sewers in the town receive the rain run off the back roofs and impervious surfaces connected with the house."

Therefore, in regulating the scale on which these works are to be constructed, attention must be given not alone to present and future population, but to the increase of subsoil water leaking into the sewers and of roof and yard water clandestinely introduced into them — a very uncertain element of the calculation. However great

it may be, an addition must be made to it to provide for the infiltration of soil water *en route*, especially after the main sewer dips below the permanent water-table of the ground. All this foreign water introduced into the sewers becomes foul water and must be treated at the same cost with the much smaller volume of actual domestic sewage provided for.

Concerning the relative advantages of broad irrigation and intermittent filtration, the case is, in the main, well stated. Doubtless the former would be used with the latter as a means of relief or as a means of agricultural advantage, much more generally than the commission has assumed. This would be regulated by experience.

The requirement that, so far as possible, irrigation-areas shall be removed beyond the limit of the Boston water-shed, seems fanciful, when we consider the manner in which the streams of that water-supply receive their chief contributions. The amount of water flowing to them over the surface of the ground is insignificant, when compared with that which comes to them from what Mr. Clarke aptly describes as a "wet sponge" — the saturated subsoil of the district.

Rainwater and other surface-water, however impure it may be, is purified before it penetrates far into the earth. Whether it be the slops thrown over the back-yards of a town, or that which soaks into the surface of the street, it does not descend far before it is essentially purified. The same would be true of sewage intermittently delivered on to ground prepared for its purification.

The same is *not* true with reference to the foul water entering the soil at lower depths. Every cesspool, every privy-vault, every leaking house-drain, every leaking town-sewer, delivers its foul flow into ground that is powerless to purify it except by dilution. The stream flowing through a porous subsoil toward the river by which it is carried away, cannot pass under a small cesspool-village without receiving enormously more filth, and filth of an enormously more dangerous character than could possibly be derived from any such system of filtration as a modern community would think of tolerating in connection with its sewage-works. If all of the sewage of Natick and outh Framingham were filtered through a field five rods away fromS the bank of the river (under the most ordinary regulation), the amount of organic matter and the amount of infection that would

thus reach the river would be as nothing compared with what would come with the unfiltered sewage above referred to, entering the underground stream directly at hundreds of points throughout these two towns, as it would still continue to do after the completion of the proposed work.

It is not always easy to define a water-shed. It is by no means always bounded by the top of the ridge of land bordering it. It is not seldom that a town, lying on a slope belonging to one water-shed, really belongs, so far as its subsoil water is concerned, to another water-shed, for the underground currents are controlled by sub-surface-formation, not by topography. A main sewer, built to carry the sewage over a long course, and to discharge near a river not belonging to the Boston basin, would probably deliver enough crude sewage by the way, through leaking-joints, to contaminate seriously the subterranean water-flow of the Boston district.

The report is, therefore, open to the criticism that it evinces too little confidence in the purification that may be effected by the process which it recommends, and has disregarded a source of impurity which is serious at the point of origin, and which may be greatly extended and distributed by the very process recommended to remove it. Sewage cannot safely be carried through a water-bearing, porous soil in sewers of ordinary construction, for these cannot always and certainly be known to be tight.

There can be little doubt that the greatest security — and a much-needed security it is — will be gained by avoiding, so far as possible, all transportation of sewage. It should be got out of the deep ground as soon as possible, and the purifying process should be applied as near as may be to the point of production.

Concerning the danger to which the water-supply is subjected, the consulting engineers say : —

" The sewage must be very thoroughly treated before entering them, to guard against the transmission of disease, liable to be produced by specific poisons or infectious germs. It is not possible to set up an absolute standard for this purpose. Although the water may be clear, and chemical analysis may show it to be of good quality, it can still hold a virulent poison from a previous sewage pollution. Mr. R. Pum-

pelly has shown, by experiments on the filtering capacity of soils, that otherwise pure water readily carries bacterial infection along with it when percolating through sand and other common materials of the ground."

It is possible that clear water, which chemical analysis would indicate to be of good quality, can hold such virulent poison. There is no evidence to show that water, made clear and pure by intermittent filtration or by irrigation-treatment, does hold such poison, and the probabilities are all against it. Pumpelly's experiments are not at all in point. Those experiments related only prospectively to the filtering capacity of *soils*. The nearest approach to a soil used in any of those experiments was loess taken forty feet below the surface, and in nowise comparable with ordinary soil as a purifier of foul waters. Most of the experiments were made with calcined sand or other sterile media. All that they proved was, that sterilized sand, asbestos, pure charcoal, kaolin and loess will not remove certain bacteria from water filtered through it, and this has nothing whatever to do with the problem in hand.

No instance has come to my knowledge, nor do I believe that an instance has ever been recorded, where sewage filtered through surface-soil, with a reasonable intermittence of application, has ever carried the germs of disease into the subsoil. In investigations made at Gennevilliers it was found that, while the sewage applied at the surface contained over twenty thousand living organisms per cubic centimeter, the effluent taken from the under-drains, through which the purified sewage passes away, contained only a dozen harmless bacteria. One closely-covered, unventilated cesspool, standing within the drainage-reach of a brook, would probably deliver more "germs" in a day, than a well-used irrigation-field of ten acres would deliver to the subsoil stream flowing under it in a year.

The conditions established in the report, for the application of intermittent filtration indicate that, wherever possible, there should be a great depth of well-drained earth between the surface and the permanent water-level of the ground. This is well, of course, as facilitating thorough aeration, and possibly as increasing the future purifying capacity of the area, but it is not imperative. The purifi-

cation takes place very near to the surface, and it is effected by processes which, under natural conditions, are not active at a great depth. Therefore, while it is advantageous to secure a depth of six feet or more, it is not worth the inordinate cost of heavy grading which such a condition would often imply. A modification of the recommendations, in this respect, would make many an area available quite near to a town, while ground meeting the more rigid requirement could be reached only at much expense, and at the risk of fouling the ground-water with crude sewage in transit.

It would seem that, in this respect, as in some others, too much reliance has been placed on the actual experience of English-sewage farms. It should be remembered that these farms were established, and the general method of their management, as well as the theory of their operation, were pitched, fifteen or twenty years ago. As English engineers sometimes fail to adopt new ideas till others have made them old, there has been no recent material modification of the principle of their construction and management. There has, during this time, been a very material increase of knowledge on the subject, and if all the sewage-farms of England could be blotted out, and if the art could be considered anew, in the light of what is now known, some important modifications would be made. Therefore, while the experience there gained is most convincing and of great value, we ought not to regulate the scope and scale of our works according to what we find there.

It is *not* necessary that broad-irrigation farms should be level, or nearly so; it is only desirable. However irregular the surface, and however steep its slopes, it is susceptible of a complete and sufficiently uniform flooding by processes well-known to those who arrange works of irrigation, where even a steep mountain-side is made to receive an adequate flow in all its parts. Then, too, it is important that any system of irrigation should also be *only* a system of infiltration. No sewage should ever, unless by a method securing long exposure, flow to a surface-carrier which would lead it to a water-course; the area covered by the discharge of sewage should be more than large enough to absorb it completely. This is a matter of easy regulation, and there would be no excuse, were such a system

adopted, for sewage from any half-well arranged separate system ever reaching a water-course before filtration. The ease with which this restriction could be enforced would be greatly aided by a suitable level tract available for more intensified filtration when the ground might be saturated with rain, or when, for any other reason it was desirable to dispose of the flow differently.

In looking over the whole subject, it seems curious that five gentlemen selected by the highest authority as fittest for the conduct of this study, as well as the three engineers chosen by themselves to aid them, should have failed so signally to acquaint themselves with the present state of human knowledge concerning it. Indeed, they seem, one and all, except for a brief foot-note by Mr. Clarke, to be quite unaware of the existence of the most interesting, the most important and the most useful facts that have ever been established in connection with the purification of sewage by application to land. The literary fancy of the commissioner who wrote the report was inspired by a recognized effect, of which he did not recognize the cause, when he referred to what could be done by "the earth at a touch," but nowhere in the whole document is there more than Mr. Clarke's casual allusion to the now well-known action by which alone this touch is made effective.

So far as scientific knowledge is concerned, this report might have been written a dozen years ago, before such knowledge existed. There is evinced an implicit and all-sufficient faith in the practical authorities of England; while the achievements of the biologists of England, of Germany, and of France, seem hardly to have been suspected. Tyndal, Warrington, Pasteur, Schloesing, Muntz, Koch and others who have developed the true theory of putrefaction and nitrification, seem not to have been thought of in this connection. Yet the practical operations of beer-making have not been more clearly shown to be governed by the agency of micro-organisms than have the practical operations of sewage purification.

The failure to give weight to this new knowledge would be of less consequence — but it would still be of consequence in a learned essay like this — if the neglected knowledge were not necessary to the giving of sound advice. Until very lately we have pinned our faith

to "aëration," "oxidation" and "the action of vegetation," and have tried to guess how we might best suit our projects to the methods thus suggested. We now know that, so far as the removal of nitrogenous matters from sewage in the soil is concerned, aëration is a condition, oxidation is an effect, and the action of vegetation is an unneeded sequel to the real purifying cause. The cause itself lies in the life processes of minute organisms which, *and which alone*, compass the complete destruction of the filth that it is our aim to annihilate.

An attempt to tell a community how to get rid of its organic wastes by soil purification which is not based on what is known of these processes — comparatively little though it is — is empirical. Before the facts were known, such an attempt was more than justifiable; now that they are known, it is hardly to be passed over without comment in the case of such thorough and costly work as that under consideration.

Tested by existing positive knowledge, the recommendations of this commission, and the hypotheses on which they are based, are seen to need much reconsideration and modification. In such reconsideration the following facts, among others, should be regarded: —

1. It would be extravagant, under such regulations as would necessarily be enforced in Massachusetts, to adopt the English estimate of one acre to each one hundred of the population. That means providing for an enormous amount of storm-water, often for very careless farming, and generally for a very wide margin to spare. If the Massachusetts towns were to be sewered on a strictly separate system, which no English town is, it would be perfectly safe to provide one acre for each five hundred of the population. Indeed, wherever the soil is open and free, this figure might be doubled, and that, too, without interfering with an important agricultural use of the sewage, as at Gennevilliers, where the sewage never flows over the land at all, all being absorbed laterally from ditches, and where the agricultural result has been so remarkable as to increase the rental of the land fivefold.

2. Sewage, as such, is not taken up by crops. Before its fertiliz-

ing parts become available for their use, their combinations have been broken down and their organic character destroyed.

3. Sewage does not contain a "virulent poison," using the words in their ordinary acceptation. Its morbific effect is due to organized and living entities. These are not immortal. They are subject to the dissolution that awaits all living things. They seem to be peculiarly subject to the action of the bacterium which produces ordinary putrefaction. Experiments in the Surgeon-General's laboratory at Washington have shown that in the cultivation of specific germs it is as important to exclude the *bacterium-termo* as it is in starting young vegetables to get rid of "pusley." If this greedy scavenger once gains a foothold he sweeps the gelatine field clean of all artificial cultures. There is not the least reason to doubt, and there is much reason to suppose, that in the soil, and in an aërated stream, it performs the same office, except, in the latter case, under very low temperatures. In the soil the sewage supplies the requisite heat even in winter.

4. There is also reason to believe that the organic parts of sewage, like all other organic wastes added to the soil or to the river, or so much of them at least as is not used as food by insects, fishes, etc., is destroyed always *and only* by a process akin to putrefaction. This is a process of oxidation which cannot take place without the intervention of life-processes. This being the case, what we have to provide are the conditions which are best suited to the development of the destroying organism. This involves aëration, it results indirectly in oxidation, and it furnishes pabulum for vegetation, if vegetation is there. The destruction of the waste must take place before roots can act on it. Vegetation is not necessary for purification.

The purification at the Sherburn Prison may be defective. The conditions are difficult — more difficult than was understood when the work was done (in 1879) — but the only evidence of impurity that has ever come to my notice is the detection of chlorides and nitrates in the outflow. It is now known that, from a sanitary point of view, chlorides and nitrates, while they indicate a sewage origin, indicate also the annihilation of the sewage character. They are harmless mineral matters, which, if unaccompanied by incompletely purified sewage, may be admitted into drinking-water streams without disadvantage.

5. The process of destruction, under natural conditions, takes place only in or very near the fertile soil at the surface — probably to the extent of at least nine-tenths, within the first six inches, and practically not at all below a depth of twelve inches. We have as yet no means of knowing how far below the surface the activity of the process may be carried by overdosing the surface layer and sending impurities farther down. The indications are that it would never go much below twelve or fifteen inches. Therefore, while an additional four or five feet of loose gravel or sand may facilitate the escape of the purified water and hasten the admission of air, we can get on with much less than this, and it would often be worth while in the interest of economy as well as of fertility, to double the breadth rather than the depth. If this is admitted to be true, the proposed extra expenditure of $45,000 at Westborough is not necessary, and the same condition would probably obtain in other cases considered.

6. The destroying organisms above referred to being active only in the surface soil, there exists, so far as we yet know, no substitute for them in the subsoil, however porous. The danger to our water courses comes chiefly from the leakage of filth at considerable depths especially of filth which has fermented without sufficient access of air. It is here that we ought chiefly to look for our means of protection. Not only should everything be done that can be done to make local drains and sewers tight and to abolish cesspools and privy vaults altogether, but we should, as far as possible, avoid the risk that inevitably attends the transportation of sewage through deep conduits, as these are practically certain to be made. This may not be avoided within the towns themselves, but it seems most unwise to incur the further risk of conveyance through long collecting sewers.

There are other details which should be regarded in any attempt to solve such a problem as the one in hand, but these are enough to indicate the insufficiency of the work described, and to suggest doubts as to the wisdom of the recommendations made in this report.

Should the subject be taken up again, with due regard to the facts above suggested, the scheme devised will have a much less gigantic aspect; the result will be better, and the cost will be less.